WATER QUALITY EVALUATION

Northgate South Lot

Prepared for

Seattle Public Utilities

April 2004

Note:

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WATER QUALITY EVALUATION

Northgate South Lot

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NORTHGATE STAKEHOLDERS GROUP
South Lot Water Quality Evaluation Report
May 11, 2004 Meeting Handouts from
Dept. of Planning and Development

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Executive Summary

The City of Seattle (City) is in the process of evaluating three alternative drainage designs for the south lot as directed by the Northgate Framework Resolution 30642. Herrera Environmental Consultants was retained by the City to develop a water quality evaluation method and evaluate the water quality performance for each of the alternatives. The three alternatives outlined in the resolution and included in this analysis are 1) Daylight existing flows, 2) a Natural Drainage System (NDS) and 3) a Hybrid of daylighting and natural drainage system concepts.

The objective of this analysis is to provide an "apples-to-apples" comparison of the relative water quality benefit expected from each of the different alternatives. The metrics chosen for this study are mass of Total Suspended Solids (TSS) and Total Zinc (Total Zn) removed per year for the entire drainage area and also on a per acre basis. The method involves three basic steps, including:

Step 1 – Estimate pollutants generated for the entire drainage area

Step 2 – Determine pollutant loadings to south lot facilities based on pollutant generation, pretreatment, and diversions upstream of the south lot facilities

Step 3 – Estimate mass of pollutants removed by south lot facilities.

In summary, the Daylight option and the Hybrid North Basin are predicted to provide modest, but not significant water quality treatment. On a per acre basis, the NDS would be expected to provide the highest level of water quality treatment per acre treated. For the total drainage area, the results indicate that the Hybrid Main Basin alternative would be expected to provide the highest level of water quality treatment.

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Introduction

The City of Seattle (City) is in the process of evaluating three alternative drainage designs for the south lot as directed by the Northgate Framework Resolution 30642. Herrera Environmental Consultants was retained by the City to 1) develop a water quality evaluation method and 2) perform the agreed upon water quality evaluation for each of these alternatives. As part of this process, Herrera was asked to reach agreement from the full evaluation team that included SPU staff and representatives involved in the development of each design option[1]. The three alternatives included in this analysis are outlined in the Northgate Framework Resolution as follows:

- Daylight existing flows
- Natural Drainage System (NDS)
- Hybrid—a combination of daylighting and natural drainage system concepts.

This report provides a description of the water quality evaluation performed for several drainage design alternatives being considered for the south parking lot of Northgate Mall in Seattle, Washington. The site covers approximately 2.7 acres and is located just south of the mall, bounded to the west by the Metro Park & Ride facility, to the north by NE 103rd Street, to the east by 5th Avenue NE, and to the south by NE 100th Street. Figure 1 provides a vicinity map of the project site.

The objective of the analysis is to provide an "apples-to-apples" comparison of the relative water quality benefits that may be expected from each of the different alternatives. The "apples-to-apples" metrics chosen for this study are mass of Total Suspended Solids (TSS) and Total Zinc (Total Zn) removed per year. Although water quality has a broad range of parameters, TSS and Total Zinc were selected by the team for this analysis for several reasons. TSS is a typical indicator of the quality of urban stormwater runoff and provides a good index of expected treatment for most particulate bound pollutants. Total Zn was selected because this constituent is typically used as an indicator of metals—a water quality issue of concern for aquatic biological health. Furthermore, literature-based and measured water quality data within the basin were available for both of these constituents, and both pollutant loading and treatment efficiencies for these indicators have been historically and relatively accurately modeled.

Since the various alternatives being analyzed provide treatment for a broad range of contributing area, results are also reported in terms of mass removed per acre per year. This provides additional information useful in assessing the relative performance efficiencies of the alternatives.

[1] Evaluation team included Miranda Maupin, Chris Woelfel and Beth Schmoyer from SPU, Kathy Robertson and Greg Giraldo from SvR Design, Peggy Gaynor from Gaynor Inc., and Ken Nilsen from PACE Inc.

This water quality analysis is based on the current conceptual designs for each alternative and if appropriate, could be refined during preliminary engineering once an alternative has been selected. The remainder of this report provides a conceptual description of the alternatives, the methods used for water quality analysis, and the results from this study.

Description of Alternatives

This section provides a description of the alternatives being considered for the south lot. These alternatives include daylighting, NDS, and a hybrid approach. Several variations on each of these three general alternatives were evaluated for this study and are described below. In addition, pretreatment from the existing North Seattle Community College (NSCC) wetlands was considered for the flows routed to the daylight and hybrid alternatives. The wetlands receive stormwater runoff from approximately 72 acres and provide approximately 26,100 ft^3 of available storage[2].

Daylight

The daylight alternative would create a constructed naturalistic channel by excavating to a maximum depth of approximately 25 feet and removing the existing underground 60/72-inch pipe. Baseflow and stormwater runoff from the entire contributing area of approximately 670 acres would be routed through the constructed channel. Figure 2 shows the area that would drain to the daylighted channel.

A typical design cross-section provided in the daylight conceptual design and feasibility report (GAYNOR and PACE, 2001) was used for this analysis. The cross-section contains a low flow channel and middle and high floodplain terraces. The low flow channel is 4 feet to 5 feet wide and approximately 0.6 feet deep. The middle terrace has a minimum width of 12 feet and is 0.9 feet deep. The total cross section width is approximately 20 feet. The longitudinal gradient would be very flat, with less than a 2 foot drop over an 800 to 900 foot length. This flat gradient may be expected to be relatively stable (i.e., not subject to major downcutting), since elevations at the upstream and downstream ends of the reach will be constrained by culverts.

The GAYNOR and PACE report (2001) provides only a conceptual level of design. Many details important to the analysis of a daylight alternative have not yet been defined. One such consideration is whether the channel is designed to be deformable (an active, meandering channel) or non-deformable (stabilized); therefore, analysis of a potential future condition for a deformable channel was also performed for this study. Cross-section information for this potential future condition was based on channel width, channel depth and gradient data for the flattest portion of the Park 6 reach of Thornton Creek, which lies just downstream of the south lot. This portion of Park 6 lies between 8th Avenue NE and 9th Avenue NE and has a gradient of approximately 1.3 percent. Based on this reference reach, the potential future condition assumed a 10-foot wide and 1.5-foot deep active channel[3]. As mentioned above, the constructed daylighted channel within the south lot would have a very flat gradient and would be constrained

[2] Based on information provided by Chris Woelfel from Seattle Public Utilities (personal communication, April, 2004).
[3] Based on SPU Thornton Watershed Assessment Database for channel condition.

on both ends by culverts. Therefore, this deformable condition may be conservative in terms of the degree to which downcutting and channel widening may be expected.

The mechanisms of water quality treatment considered for the daylighting alternative were surface filtration and sedimentation within the middle terrace. The upper terrace was not considered because the feasibility report estimates that the recurrence interval required to access this terrace is approximately 1.2 years. Thus, the upper terrace would not provide treatment during a typical year.

Natural Drainage System (NDS)

The NDS alternative constructs a series of vegetation-lined bioretention swales at existing surface grade to provide water quality treatment for stormwater runoff from adjacent areas. The existing 60/72-inch pipe beneath the south lot would remain in place with this alternative.

A series of five swales would be constructed. Each swale would have a sediment pool and a 6-inch high leveling weir at the upstream end that discharges to the swale(s). At the downstream end of each swale, a catch basin would discharge treated runoff directly to the existing 60-inch conveyance pipe. Each swale would receive runoff from different drainage areas and would discharge treated runoff directly to the existing 60-inch pipe. Each swale would be approximately 220 feet long, have a 10-foot bottom width, a 1 percent longitudinal slope, and a hydraulic residence time of at least nine minutes. The design peak flow capacity for each swale is 2.5 cfs. Each swale includes filtering vegetation, infiltrative amended soil and gravel beds. Two options for the NDS were evaluated; one in which runoff from 99 acres is routed to the facility and one in which runoff from 86 acres is routed to the facility. Figure 3 shows the areas draining to the NDS for both of these options.

The NDS swale design is the same for both options. The water quality treatment mechanisms considered for the NDS included surface filtration through vegetation and modest infiltration into the amended soil bed and subsurface soil.

Hybrid

The third alternative is a hybrid that combines features from the daylighting and NDS alternatives. The hybrid creates a naturalistic channel to convey baseflows and provide conveyance and treatment of stormwater runoff. A typical cross-section contains a low flow channel that conveys the untreated baseflows through the system, and a broad, relatively flat, and vegetated floodplain, which provides conveyance and treatment for stormwater. The floodplain vegetation will include grasses and sedges that will be up to a foot or greater in height. Several weirs with openings that will be placed within the channel are sized to allow baseflow to flow through without detention. The weirs detain stormwater within the floodplain swale, causing the stormwater to back-up and spread out over the vegetated terrace. As the storm hydrograph recedes, all of the detained water drains through the weir openings via the low flow channel. Based on the intent of the conceptual design, weir overflows are expected to occur infrequently, for events with a recurrence interval of 100 years or greater.

Two hybrid options were evaluated: Hybrid Main Basin and Hybrid North Basin.

1. The Hybrid Main Basin receives runoff from the entire 670-acre basin that contributes flow to the underground 60/72-inch pipe. The design proposes to install a 5-foot weir in the underground pipe at the upstream end of the entrance to the constructed channel. This weir will create a backwater effect within the pipe, which will raise the water surface elevations at the channel entrance and slightly increase the longitudinal channel gradient of the constructed channel to be approximately in the range of 0.4 percent to 0.6 percent.

2. The Hybrid North Basin receives runoff from a subset of the Hybrid Main Basin drainage area and has a contributing basin area of approximately 126 acres. For this option, the in-line weir is not needed to achieve a longitudinal channel gradient within the range specified above. Figure 4 shows the areas contributing runoff to Hybrid Main Basin and Hybrid North Basin options.

The water quality treatment mechanisms considered for both hybrid alternatives include extended detention for stormwater detained by the weirs, and surface filtration and sedimentation via flow through the floodplain swale vegetation. The Hybrid Main Basin option also includes sedimentation within the backwater pipe. Assuming a 600-foot long, 72-inch diameter pipe with a 0.11 percent longitudinal slope and sediment depth of approximately 1/6 the pipe diameter, the available storage volume in the backwater pipe appears to be insufficient to offer appreciable sedimentation. Any sedimentation that might occur would also likely be subject to resuspension during storm events. Therefore, sedimentation in the backwater pipe was considered negligible for this analysis. Extended detention and surface filtration/sedimentation over the floodplain swale occur as an integrated process within the constructed channel; however, surface filtration/sedimentation was considered the dominant process by the team and therefore is the mechanism chosen by the team to evaluate the treatment efficiencies of the floodplain swale. Evaluating only the dominant treatment process, rather than both processes, represents a conservative assumption for the evaluation of potential treatment benefits associated with the hybrid alternative.

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Methods for Evaluating Water Quality Treatment Benefits

Figure 5 provides a schematic representation of the evaluation process used to complete the water quality evaluation for each of the south lot alternatives. The method involves three basic steps, including:

- Step 1 – Estimate pollutant generation rates
- Step 2 – Modify pollutant generation rates to represent loading rates based on pretreatment facilities and percentage of flows diverted to south lot facilities
- Step 3 – Estimate mass of pollutants removed by south lot facilities.

The remainder of this section provides an overview of the above steps. A detailed description of the methods and data inputs for each step is provided in Appendix A.

Step 1 – Estimate Pollutant Generation Rates

Pollutant generation rates are defined for this study to include the average mass per year of TSS and Total Zn generated within the entire area that contributes runoff and pollutant loading to each of the proposed south lot facilities. This first step does not take into account pollutant removal that occurs up-system (for example from the NSCC wetlands) or flows from the drainage area that by-pass the south lot facility. Two methods were used to estimate the pollutant generation rates in order to provide a basis for cross-comparing results. The primary method, Method A, uses measured water quality data from within the study area for 18 storm events sampled. The second method, Method B, uses published factors for several urban land use types. Both methods provide valuable insight as to the range of possible pollutant loadings for the various alternatives being analyzed. While it was considered important to consider results from two independent methods, a stronger emphasis is placed on Method A because the SPU water quality data are judged to be high quality and representative of the area being studied. The following text provides more detailed descriptions of both methods.

Method A uses measured water quality data from 18 storms collected at the southwest intersection of NE 100th Street and 1st Avenue NE. Figure 6 shows the area draining to the water quality data collection point, which covers approximately 208 acres of mixed land uses including I-5. Figure 7 shows the flow and water quality data for the storm events sampled, which include 18 storm events during the monitoring period December, 2001 to May, 2002. Using these data, regression equations were developed to relate expected TSS and Total Zn generation rates based on stormwater volume. For each alternative analyzed, the mean annual stormwater volume was input to predict pollutant generation rates for the contributing areas. The regression equations are provided in Appendix A. Table 1 provides a summary of the inputs and results for this step.

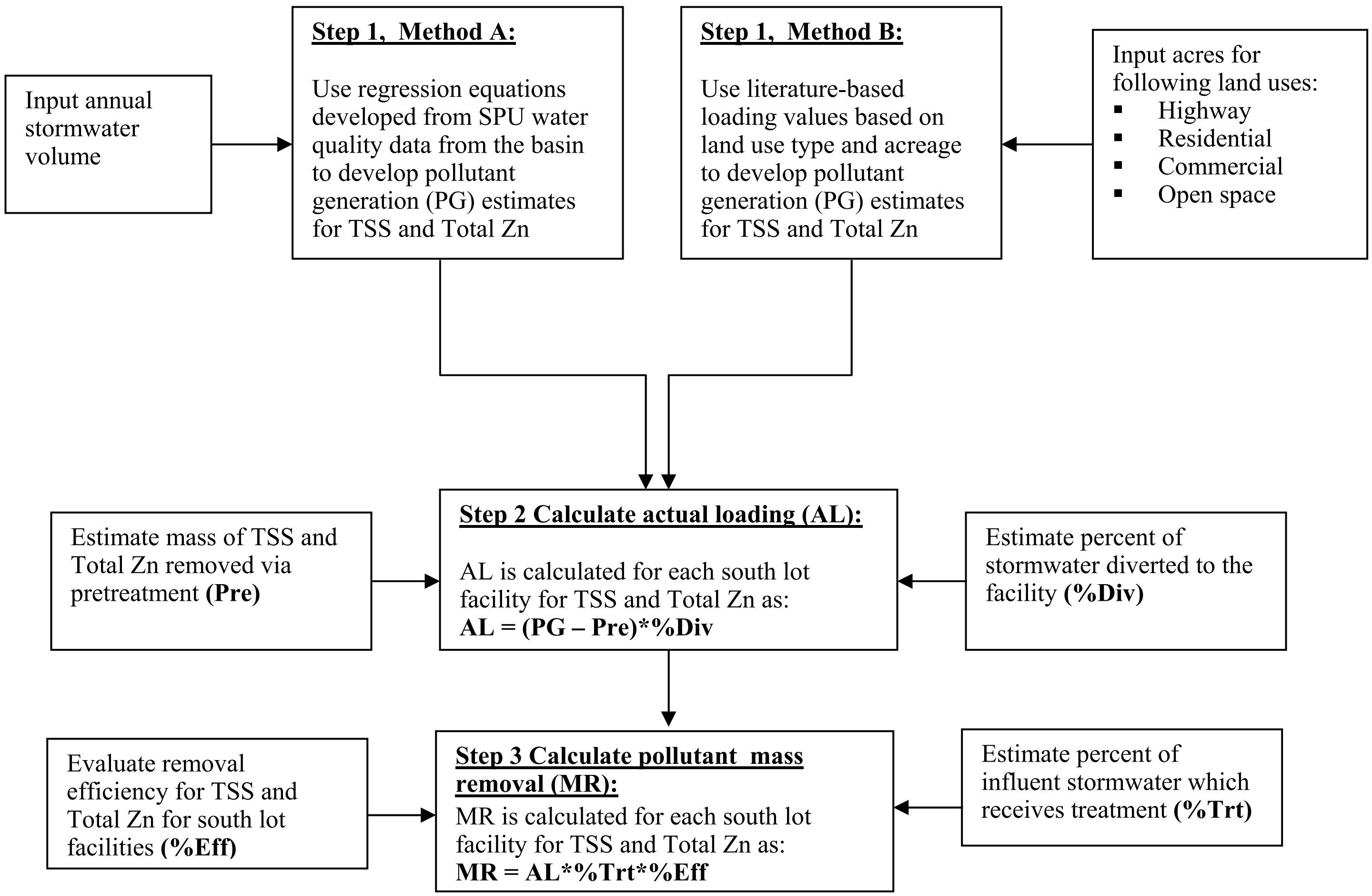

Figure 5. Outline of methods used to perform water quality evaluation for the Northgate South Lot alternatives.

Table 1. Estimated pollutant generation rates based on Method A – using SPU water quality monitoring data from within the study area.

Alternative	Mean Annual Flow [a] (cfs)	Baseflow [b] (cfs)	Mean Storm Flow [c] (cfs)	Mean Storm Volume [d] (L/day)	Pollutant Generation Rates [e] (kg/yr)	
					TSS	Total Zn
Daylighting - Non-deformable (670 acres)	1.7	0.7	1.0	2.4E+06	55,659	94.9
Daylighting - Deformable (670 acres)	1.7	0.7	1.0	2.4E+06	55,659	94.9
NDS (99 acres)	0.2	0.0	0.2	6.1E+05	14,753	24.3
NDS (86 acres)	0.2	0.0	0.2	5.3E+05	12,905	21.1
Hybrid Main Basin (670 acres)	1.7	0.7	1.0	2.4E+06	55,659	94.9
Hybrid North Basin (126 acres)	0.3	0.2	0.1	2.9E+05	7,228	11.7

Notes:
[a] Based on HSPF simulated mean annual flow at 5th Avenue NE and NE 103rd Street (Entranco, 2000), scaled by ratio of contributing basin area.
[b] Baseflow estimates provided by SPU.
[c] Mean storm flow computed as mean annual flow minus baseflow.
[d] Mean storm volume converted from mean storm flow.
[e] Pollutant generation estimates based on Equations 1 and 2 (Appendix A) using Mean Storm Volume as input. The average daily estimates of initial loading were then multiplied by 365 to represent annual loadings.

The second method for estimating pollutant generation rates, Method B, used typical pollutant loadings from urban land uses, including commercial, residential, highway, and open space. The pollutant loading factors were taken from Horner et al. (1994). Table 2 provides a summary of the loading factors used.

Table 2. Pollutant loading factors based on land use distribution (Horner et al., 1994).

Land Use	TSS (kg/acre-year)	Total Zn (kg/acre-year)
Commercial	453.6	0.95
Residential [a]	138.3	0.20
Highway	399.2	0.95
Open Space [b]	1.4	0.02

Notes:
[a] Residential represents an average of high and medium density values reported in the literature. This is intended to account for a mix of single- and multi- family land uses within the study area.
[b] Estimates of Total Zn loadings for open space land uses represent and average of Total Zn loading values for forest and grass/pasture as reported in the literature.

For each alternative being evaluated, the distribution of land uses was combined with the loading factors in order to provide the second estimate of pollutant generation rates for cross-check purposes. Table 3 summarizes the input land use distributions by alternative and the results.

Table 3. Pollution generation rates estimated based on Method B – using loading factors based on land use distribution.

	Area [a] (Acres)					Initial Loading [b] (kg/year)	
Alternative	Comm.	Res.	Hwy	Open Space	Total	TSS	Total Zn
Daylighting - Non-deformable (670 acres)	364.1	227.0	49.8	29.5	670.3	216,441	441
Daylighting - Deformable (670 acres)	364.1	227.0	49.8	29.5	670.3	216,441	441
NDS (99 acres)	28.9	66.4	0.0	3.2	98.5	22,293	41
NDS (86 acres)	16.1	66.4	0.0	3.2	85.7	16,487	29
Hybrid Main Basin (670 acres)	364.1	227.0	49.8	29.5	670.3	216,441	441
Hybrid North Basin (126 acres)	89.4	25.5	8.1	3.4	126.4	47,298	98

Notes:
[a] Land use distribution data provided by SPU on March 31, 2004.
[b] Initial loading estimates for Method B are based on loading factors from Horner et al. (1994)

Comparison of pollutant generation rates indicates that Method B produces higher estimates than Method A. The estimates from both methods are within an order of magnitude, with Method B estimates ranging from roughly 2 to 8 times higher than those from Method A. As mentioned above, preference is given to Method A for this analysis because the site specific data are considered more representative than the literature-based approach, which uses data compiled from studies across the nation.

Step 2 – Modify Pollutant Generation Rates Based on Pretreatment and Percent of Flows Diverted to Facility

The first step estimated the total mass of pollutants generated over the entire contributing area. This second step modifies these loading values to take into account up-system pretreatment and the amount of the basin flow diverted to the facility on the south lot. The equation used to estimate the modified pollutant loadings is provided in Figure 5 and also in Appendix A.

For the daylighting and hybrid alternatives, runoff from approximately 72 acres of the contributing area is treated by the existing NSCC wetland treatment facility upstream of the alternatives facilities. The Nationwide Urban Runoff Program (NURP) method for sizing wetponds was used to gauge the treatment efficiency of the wetland facility. This method uses the ratio of basin volume (wetland volume in this case, V_b) to runoff volume, V_b/V_r. The V_b/V_r ratio for the wetlands was estimated to be 0.3. Detailed discussion of how this ratio was computed is provided in Appendix A.

In order to evaluate the treatment afforded by the wetland facility, the percent of the pollutant generation subject to treatment was estimated. This percent was assumed to be proportional to drainage area, or the ratio of area draining to the wetland facility to total contributing area for the daylighting and hybrid alternatives. This ratio was applied to the pollutant generating rates developed using Methods A and B. Table 4 provides a summary of the pollutant generation rates, mass removed by wetland facility, and resultant pollutant loads for both Methods A and B.

Table 4. Estimates of pollutant generation rates (PG), mass removed during pretreatment (Pre), and actual loading (AL) for Methods A and B.

Alternative	PG (kg/year)		Pre [a] (kg/year)		AL [b] (kg/year)	
	TSS	Total Zn	TSS	Total Zn	TSS	Total Zn
Method A - Using SPU Water Quality Monitoring Data for Downstream Defender						
Daylighting - Non-deformable (670 acres)	55,659	95	1,786	2	53,873	93
Daylighting - Deformable (670 acres)	55,659	95	1,786	2	53,873	93
NDS (99 acres)	14,753	24	0	0	14,753	24
NDS (86 acres)	12,905	21	0	0	12,905	21
Hybrid Main Basin (670 acres)	55,659	95	1,786	2	32,324	56
Hybrid North Basin (126 acres)	7,228	12	1,230	1	5,998	11
Method B - Using Loading Factors Based on Land Use Distribution						
Daylighting - Non-deformable (670 acres)	216,441	441	12,788	13	203,653	428
Daylighting - Deformable (670 acres)	216,441	441	12,788	13	203,653	428
NDS (99 acres)	22,293	41	0	0	22,293	41
NDS (86 acres)	16,487	29	0	0	16,487	29
Hybrid Main Basin (670 acres)	216,441	441	12,788	13	122,192	257
Hybrid North Basin (126 acres)	47,298	98	11,383	12	35,915	86

Notes:
[a] Assuming treatment efficiencies of 30 percent and 15 percent for TSS and Total Zn, respectively. Development of these treatment efficiencies is described below.
[b] AL = (PG-Pre) x %Div. For the Hybrid Main Basin alternative, %Div was evaluated as 60 percent. For the remaining alternatives, %Div was evaluated as 100 percent.

Actual pollutant loadings also take into consideration the effect of a flow splitter for the Hybrid Main Branch alternative, which would divert an estimated 60 percent of the annual storm volume to the facility and bypass the remaining 40 percent to the existing 60/72-inch underground pipe. For the Hybrid Main Basin alternative, the 60 percent diversion factor was applied to the difference between pollutant generation and pretreatment to compute actual loading. For the remaining alternatives, 100 percent of the flows are assumed to be diverted to the facilities.

Step 3 – Mass of Pollutants Removed by South Lot Facilities

The final calculation step involves calculating the mass of pollutants removed by the south lot facilities. The mass removed is based on the loads calculated in Step 2 multiplied by two factors. The first factor represents the percent of the annual volume diverted to the facility which actually receives treatment. The second factor represents the treatment efficiency within the south lot facility. The equation for calculating the mass removed is provided in Figure 5 and also in Appendix A. Appendix A also provides detailed discussion of how the factors were evaluated for each alternative.

The percent treated variable accounts for the percent of the stormwater volume diverted to the facility that is actually expected to receive treatment. In the daylight alternative, this translates to the percent of the volume in the channel that accesses the middle terrace floodplain surface. For the non-deformable daylighting scenario, the percent of the annual stormwater treated was estimated to be approximately 20 percent. For the deformable daylighting scenario, the percent of the annual stormwater treated was estimated to be approximately 5 percent. Appendix A provides detailed discussion of how these values were derived. The NDS is designed to treat stormwater runoff for events up to and including the 6-month, 24-hour event which corresponds roughly to 90 percent of the annual stormwater volume. For the hybrid alternative, the same 90 percent value was used, assuming that the system will be designed so that all baseflows will be contained in the low flow channel and 90 percent of all storm flows will overflow the low flow channel and access the floodplain terrace.

Treatment efficiencies for the south lot facilities were based on multiple sources, including a national performance database (Winer, 2000) and treatment efficiency expectations established in local regulations (King County, 2004). Table 5 provides a summary of the efficiencies from these sources as well as the rationale and methods for developing the treatment efficiencies ultimately used in this study.

Table 5. Development of treatment efficiencies for various stormwater treatment practices for Total Suspended Solids (TSS) and Total Zinc (Zn).

Description of Treatment Provided by Each Alternative				Treatment Efficiencies from National Performance Database (Winer, 2000)		Expected Treatment Efficiencies Based on Local Regulations (King County, 2004)		Treatment Efficiencies Used in this Study - Values Were Based or Modified from the National Performance Database and Expected Performance from Local Regulations		
Alternative	Treatment Component of Alternative	Equivalent Treatment Practice from Winer (2000)	Treatment Mechanisms	TSS Removal Efficiency (%)	Total Zn Removal Efficiency (%)	TSS Removal Efficiency (%)	Total Zn Removal Efficiency (%)	Rationale/Methods for Modifying Treatment Efficiencies from National Database and Expected Performance Based on Local Regulations	TSS Removal Efficiency (%)	Total Zn Removal Efficiency (%)
NSCC Wetland Pretreatment - applies to Daylighting and both Hybrid alternatives	Existing NSCC wetlands (offsite)	Pond/Wetland System [a]	Sedimentation	71 (28 - 100) [b, c]	56 (16 - 100) [b, c]	80	50	King County (2004) treatment efficiencies were reduced because the wetlands are undersized. The estimated Vb/Vr = 0.3 is 10 times lower than the Vb/Vr = 3.0 required for a properly sized wetland (King County, 2004).	30	15
Daylighting	Middle Terrace	Water Quality Swales [d]	Surface filtration and sedimentation	81 (67 - 95) [b]	71 (35 - 100) [b, c]	80	N/A	Modified from Winer (2000) based on ratio of estimated residence time of approximately 6 minutes to design residence time of 9 minutes (King County, 2004).	53	30
NDS	Bioretention swales	Filtration Practices [e]	Surface filtration and infiltration	86 (63 - 100) [b, c]	88 (71 - 100) [b, c]	80	N/A	Based on median from national performance database (Winer, 2000). Noted that the range of measured performance values in the database for this practice is considered relatively narrow.	86	88
Hybrid Main Basin	Second Terrace	Water Quality Swales [d]	Surface filtration and sedimentation	81 (67 - 95) [b]	71 (35 - 100) [b, c]	80	N/A	Based on King County (2004). Using high removal efficiencies due to long residence time caused by the weirs which span the floodplain. All water during recession from weir storage contacts the floodplain vegetation.	80	45
Hybrid North Basin	Second Terrace	Water Quality Swales [d]	Surface filtration and sedimentation	81 (67 - 95) [b]	71 (35 - 100) [b, c]	80	N/A	Based on King County, 2004.	80	45

Notes:
[a] Includes data for the following treatment practices; shallow marsh, extended detention wetland, and submerged gravel wetland.
[b] Values in parenthesis represent +/- one standard deviation from the mean from the literature data.
[c] Upper bound (mean plus one standard deviation) in literature exceeds 100 percent. A maximum treatment efficiency of 100 percent was assigned in these cases.
[d] Includes data for the following treatment practices; ditches (not designed for water quality treatment), grass channels, dry swales, and wet swales.
[e] Includes data for the following treatment practices; organic filters, perimeter sand filters, surface sand filters, vertical sand filters, and bioretention.
[f] Enhanced treatment provides up to 50 percent total Zn removal based on King County Surface Water Design Manual (February 2004 Update Draft).
[g] Nine-minute residence time based on King County, 2004.

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Conclusions and Findings

The water quality benefits associated with several alternatives for the south lot of Northgate Mall have been evaluated and compared. Mass of TSS and Total Zn removed per year was used as an "apples-to-apples" metric of water quality performance. Two methods were used to compute the pollutant loading of TSS and Total Zn for each of the contributing basins in order to provide means for cross-checking results based on independent inputs and approach. The method recommended for primary consideration is Method A, which uses water quality data collected by SPU within the study area as the basis for estimating pollutant loadings. The field data collected within the study area is considered representative of the pollutant loading scenarios being evaluated.

Based on Method A, the Daylight option and the Hybrid North Basin appear to provide modest, but not significant water quality treatment. Figure 8 shows estimated pollutant removal in terms of mass pollutants removed per year. Figure 8 also shows the estimated pollutant removal in terms of mass pollutants removed per acre per year. On a per acre basis, the NDS would be expected to provide the highest level of water quality treatment per acre treated. For the total drainage area basis, the results indicate that the Hybrid Main Basin alternative removes the most TSS and Total Zn per year. Figure 9 shows results for Method B for purposes of comparison and establishment of upper bounds. The results of Method B support the above findings from Method A in terms of per acre and total contributing drainage area performance.

Based on the assumptions of this analysis, the NDS removes the most pollutants on a per acre basis and the Hybrid Main Branch alternative performs the highest total annual removal of TSS and Total Zinc.

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